# Doctrine, Technology, and War[1]

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1. Introduction

This paper aims at illuminating some of the more basic relationships between doctrine, technology, and war. The approach will be to use selected historical vignettes to shed light on these relationships. Nevertheless, the discussion will not be exclusively historical or backward looking. The deeper, more enduring linkages between doctrine, technology, and war also suggest certain bounds on how much the conduct of war can be expected to change in the decades ahead—even if the *hypothesis* of an emerging revolution in military affairs is borne out in the decades ahead. These boundaries or limits, presumably, should be of interest to anyone concerned with either air power or joint doctrine.

Why concentrate on the more basic relationships between doctrine, technology, and war—particularly at a time when so much about war seems subject to imminent change? The answer stems from a point repeatedly emphasized by Albert Wohlstetter: namely, to avoid confusing ourselves "about matters of great importance for national security."[2] Today, as during the opening years of the nuclear age, we are confronted with the likelihood of large changes in the weapons of war arising from a panoply of technological advances, especially those bearing on the gathering, processing, dissemination, and rapid exploitation of ever more precise, detailed, and synoptic information. Precision weapons, advanced surveillance platforms, and even low observability can be viewed as technologically driven variations on this overarching theme. Such changes in the prevailing means of war inevitably entail changes in other aspects of military societies. In the words of the naval historian Elting Morison: "Military organizations are societies
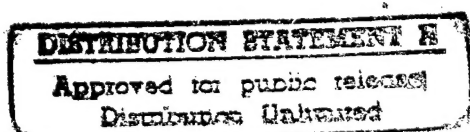
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built around and upon the prevailing weapons systems. Intuitively and quite correctly the military man feels that a change in his weapon portends a change in the arrangements of his society."[3] Confronted by such far-reaching and potentially uncontrollable changes, it is easy to lose sight of fundamentals, to lapse into the belief that little or nothing we have learned from past wars is likely to apply in the future. At best, the impression that everything about war is in flux is exaggeration. At worst, it leads us to confuse ourselves.

The discussion that follows aims first and foremost at avoiding such confusion. Of particular importance is to distinguish those aspects of future war that are likely to change from those that are not. Toward this end, we will examine, in turn, doctrine and war; technology and war; and, doctrine and technology. The result, hopefully, will be at least a few propositions on which we can risk hanging our "doctrinal hats" even in a period of considerable technological change. In addition, by concentrating on the first-order or fundamental relations in each area, there is also the possibility that the outlines of a more objective, empirically based kind of doctrine may become visible.

2. Doctrine and War

The relation between doctrine and war seems as good a place to start as any. Are there any enduring linkages between doctrine and combat outcomes? Or, to put the point more bluntly, does doctrine matter?

There is, of course, a popular tradition in the U.S. Air Force that doctrine does not count for much. In the first heady flush of combat, so goes one variant of this popular view, the dry doctrinal tomes written by staff "pinheads" are jettisoned, and "innovative" free-wheeling "operators" begin making it up as they go along in response to the pressing needs of the moment. My own reading of military history is that this view, however popular in many quarters of the Air Force, is misguided at best and nonsense at worst. Let me offer two cases in point, one a negative lesson and the other a more positive one in terms of doctrinal soundness.

The first example concerns the so-called doctrine of bomber invincibility that grew up among bomber proponents at Maxwell Field, Alabama, in the 1930s during the heyday of the Air Corps Tactical School (ACTS).[4] In the visionary and oft-quoted words of ACTS graduate and instructor Kenneth L. Walker: "A well planned and well conducted bombardment attack, once launched, cannot be stopped."[5] Over time, this view was incorporated into Tactical School texts. In April 1930, the revised ACTS text *The Air Force* boldly asserted that "a defensive formation of bombardment airplanes properly flown, can accomplish its mission unsupported by friendly pursuit, when opposed by no more than twice its number of hostile pursuit."[6] Five years later, the school's bombardment text noted that "escorting fighters will neither be provided nor requested unless experience proves that bombardment is unable to penetrate . . . resistance [from enemy pursuit] alone."[7] In short, the doctrinal thesis that American bomber advocates developed during the 1930s was that well-flown, well-led bomber formations could, even in daylight, penetrate enemy defenses *without escort* by friendly fighters and accurately bomb targets from high altitude without suffering unacceptable losses.[8]

Did this doctrinal belief have consequences for American bomber operations during World War II? The U.S. Eighth Bomber Command under (then Brigadier) General Ira Eaker flew its first bombing mission from the United Kingdom on 17 August 1942. This initial test of daylight, precision bombing dispatched twelve B-17s to Rouen in German-occupied France; these dozen American bombers were shepherded to the target and back by over a hundred Spitfires.[9] That same month the Air Staff's Air War Plans Division began undating its August 1941 estimate (AWPD-1) of the Army Air Forces' munitions requirements for defeating Germany. The fundamental view expressed in AWPD-42 was that "the heavy bomber formation was self-defending and thus escort was not required."[10] The crucial point for present purposes is that this optimism concerning the defensive abilities of *unescorted* American bomber formations was embraced by General Eaker in England.[11] As he wrote to General H. H. "Hap" Arnold in Washington on 20 October 1942:

You have probably been asked whether it is feasible to bomb objectives in Germany by daylight without fighter cover. I am absolutely convinced that the following measures are sound. . . . *Three hundred heavy bombers* can attack any target in Germany by daylight *with less than four per cent losses*. A smaller number of bombers will naturally suffer heavier losses. [Italics added.][12]

In late 1942, of course, Eighth Bomber Command did not have the planes or bomber crews to test this brave proposition. Not until the beginning of October 1943, almost a year later, was General Eaker in a position to dispatch three hundred or more heavy bombers against targets in Germany over the course of a series of missions. Since the more "vital" of these targets lay beyond the range of any long-range fighters then available, fighter escort all the way to the target and back was not possible.[13]

By the time General Eaker was in a position to test bomber invincibility, he was under considerable pressure. From Washington, General Arnold pressed Eaker to prove the viability of daylight, precision bombing; in England, British airmen like Arthur "Bomber" Harris still hoped that American airmen would abandon daylight bombing of "panacea" targets, as both the German and British air forces had already done, and join the Royal Air Force in area attacks at night.[14] Confronted with such pressures, Eighth Air Force mounted a series of six deep-penetration missions against German targets during the thirteen days spanning 2-14 October 1943. The results are well known. Including those bombers written off, these six deep-penetration missions cost Eighth Bomber Command 198 heavy bombers—roughly 37 percent of the command's average "fully operational" bomber strength in combat units during October; ignoring wounded and dead airmen in aircraft that survived the trip back to England, 166 crews totaling 1,651 American airmen went "missing in action" over enemy territory—nearly 40 percent of the command's average effective combat-crew strength that month.[15] Eighth's overall loss rate as a percentage of the 2,014 heavy-bomber sorties dispatched against German targets for the missions of 2, 4, 8, 9, 10, and 14 October 1943 was 9.8 percent, more than double the 4 percent upper limit that Eighth Air Force leaders had believed putting up 300 or more bombers at a time would guarantee. Worse, the losses per mission escalated dramatically over the course of these thirteen days as the Germans reacted to the American

daylight, deep-penetration raids. On the final mission to the ball-bearing plants at Schweinfurt—better known to the bomber crews who flew it as "Black Thursday"— German defensive measures included large-scale use for the first time of rockets fired from beyond the bombers' effective machine-gun range to break up formations, the concentration of fighter attacks on one bomb group at a time, and aggressively pressing home head-on fighter attacks from "twelve o'clock high."[16] The upshot was 60 B-17s missing in action on Black Thursday alone.

Such aircraft and crew losses constituted levels of attrition that Eighth Bomber Command could not sustain. While Luftwaffe fighters opposing these raids also sustained severe losses,[17] American hopes of conducting unescorted, daylight bombing of German targets ended in what the official history of the Army Air Forces in World War II rightly termed the "autumn crisis" of October 1943.[18] As Eighth Air Force tacticians under Major General Orvil A. Anderson wrote in July 1945:

> These deep bomber penetrations beyond fighter escort range represented a bold attempt by the Eighth Air Force to establish that heavily-armed bombers could fly deep into enemy territory with only the protection of their own defensive fire-power. The losses on some of these missions tended to prove the opposite, if the bombers were opposed by an alert and desperate enemy.[19]

Not until adequate numbers of P-38s and P-51s, properly equipped with external "drop" tanks, became available in December 1943 did it become practical for Eighth Air Force "to renew the systematic bombing under visual conditions of targets deep in Germany."[20]

The saga of bomber invincibility is, obviously, not a happy doctrinal story. American airmen got at least one vital aspect of their prewar bombardment doctrine wrong, and they paid a heavy price for that mistake in both men and machines when the test of combat arrived in the skies over northern Europe. Depressing as this story may be, though, it establishes a clear, concrete linkage between doctrinal precepts and combat outcomes. It illustrates an occasion on which prewar doctrine mattered very much insofar as it failed to take into account the operational challenges that a determined, resourceful opponent could pose for unescorted bomber formations.

That said, can we also point to happier examples in which prewar doctrinal precepts were not only validated by the test of combat, but appear to have been crucial in producing positive results? A recent case can be seen in the thinking behind the offensive air campaign that the air forces of the U.S.-led coalition conducted against Iraq from 17 January to 28 February 1991. At the core of this air campaign—both as planned and as executed—was a bold "vision of air power" as the "essential element" in all but the fourth and final phase of a theater war.[21] In the opening three phases, air power alone attacked strategic target systems deep in Iraq, achieved and maintained air superiority, and prepared the battlefield. (These opening three "phases" overlapped in execution although the relative weight of effort accorded each varied considerably during the war's first 39 days.) Only during the final 100 hours of offensive operations by Coalition ground forces did air power function mainly in a supporting role.

In the aggregate at least, the results achieved by the Desert Storm air campaign constituted the basis of one of the most lopsided military campaigns in modern military history. At an astonishingly low price in friendly lives (less than 400 Americans died during Desert Shield and Desert Storm), Iraq's air force and integrated air defenses were destroyed, disrupted, or lost to Iran; Iraqi ground forces were ejected from Kuwait and over 70 percent of their heavy equipment (tanks, artillery, and armored personnel carriers) destroyed; and Iraq's ability to threaten other states in the Persian Gulf was greatly reduced (even though significant elements of Iraq's Republican Guard escaped destruction as did the majority of Iraq's nuclear-weapons program).[22] Granted air power fell short of achieving victory on its own as some of the American airmen involved in both planning and execution had privately hoped. For a variety of reasons, a multi-corps ground offensive still proved necessary after 39 days of Coalition air operations. Nevertheless, the lion's share of the credit for the Coalition's overall military success at so small a cost in friendly lives and treasure must go to the air campaign.

What were the origins of the conceptual ingredients underlying the Desert Storm air campaign? Among other things, the air campaign emphasized: the notion of an enemy state as a "system of systems"; the direct use of air power to achieve national objectives through the judicious selection of "strategic target categories" containing enemy "centers

of gravity"; the functional disruption of target systems (as opposed to the physical destruction of individual target elements); precision munitions, especially laser-guided bombs which, when delivered from platforms like the F-111F and F-117, permitted precision attacks to be carried out at night on an operational scale ("parallel" operations); and, the F-117's stealth, which offered a capability to attack strategic targets from the opening moments of the war without first achieving traditional air superiority.[23]

Where did these ideas and concepts come from? If we set aside various historical antecedents that, in many cases, reach back to the Air Corps Tactical School, the answer is that they came largely (though not entirely) from the prewar thinking about offensive air campaigns of a small handful of individuals. Key among those individuals in terms of the role their ideas subsequently played in the planning and execution of the Desert Storm air campaign were two Air Force officers: Colonel John A. Warden and (then) Lieutenant Colonel David A. Deptula. The history of their involvement, as well as that of many others, has been documented extensively since the Persian Gulf War in Air Force-sponsored reports and histories, as well as in numerous articles and books by scholars, journalists, and military participants in the Persian Gulf War.[24] This history need not be recounted beyond a couple basic points bearing on the relations between doctrine and war. First, the Instant Thunder campaign plan developed by Warden's Checkmate group in August 1990, which was more a concept for an offensive air option against Iraq than a series of detailed air tasking orders, did provide the "conceptual base and overall blueprint" from which (then) Brigadier General Buster Glosson's Special Planning Group in Riyadh (known as "the Black Hole") and, later, Central Command Air Forces (CENTAF) worked initially to fashion the detailed operations plan for the Desert Storm air campaign executed in 1991.[25] Although two target categories (Republican Guard forces and surface-to-air missiles) were added before the war to the eleven Warden's group originally picked, and while a fourteenth (consisting of a half-dozen breaching targets) was added during Desert Storm, Instant Thunder's categories and their relative priority (as a percentage of total targets) persisted into the opening days of the air campaign. Thus, "the first days of the air campaign plan were remarkably similar to those proposed five months before by Instant Thunder planners."[26]

Second, Instant Thunder represented "a radical revision" in the way both air and theater planners had come to view the proper application of air power by the late 1980s.[27] Consider the alternative concept developed by Tactical Air Command (TAC) planners in early August 1990, with its emphasis on demonstrating resolve, incremental escalation, and concentrating air strikes on Iraqi ground forces then occupying Kuwait.[28] TAC's campaign concept was not only light years apart from Warden's conceptually, but in fact represented the mainstream of doctrinal thought within the Air Force at the time Iraq invaded Kuwait. As Colonel Edward Mann later concluded: if airpower "zealots" such as Warden and Deptula "had not inserted themselves in the planning process, the offensive air campaign plan likely would have developed in concert with the plans for ground operations during November 1990"—that is, air power would have been subordinated directly to the maneuver and perspective of corps-level ground forces.[29]

What do these brief observations suggest about relationships between doctrine and war in the case of the Gulf War? Given the unprecedented degree of success that the Warden-Deptula campaign concept subsequently achieved in the only meaningful test—actual combat—it is hardly plausible to argue that the approach chosen was misguided or wrong. Note, too, very different air campaigns than the one executed were possible, as the TAC alternative confirms.[30] The most intriguing implication for doctrine and war, however, is that key ideas underlying the Desert Storm air campaign—parallel warfare, the enemy state as a "system of systems," the emphasis on precision and stealth, the conscious goal of seeking functional disruption of whole target systems, etc.—were neither officially sanctioned at the time nor even mainstream doctrinal thinking within the Air Force. In other words, while imaginative doctrinal ideas underwrote operational success in January-February 1991 every bit as much as the flawed doctrine of bomber invincibility underwrote tactical defeat in October 1943, the notions that count in wartime need not be recorded in official prewar doctrinal publications. Why? Because the conduct of actual campaigns can, as happened in Desert Storm, be shaped by the "unofficial," "unsanctioned" doctrinal concepts of a handful of individuals.

The suggestion that Warden and Deptula's ideas about air campaigns were not officially sanctioned at the time Iraq invaded Kuwait should not be misconstrued as im-

plying that these officers had no encouragement from senior Air Force officers. While a student at the National War College during the 1985-86 academic year, Warden wrote a research paper titled, "The Air Campaign," which sought "to come to grips with the very complex philosophy and theory associated with air war at the operational level."[31] In no small part due to Major General Perry Smith's enthusiasm for the paper, it was published by National Defense University Press in 1988 with (then retired) Air Force General Charles Donnelly's endorsement that a "book of this type has been needed for a long time."[32] Subsequently, when (then) Lieutenant General Michael Dugan became deputy chief of staff for plans and operations on the Air Staff (XO), he had not only read Warden's book but was sufficiently impressed to recommend it to all officers in XO, as well as to create a special deputy directorate for war-fighting concepts (XOXW) on the Air Staff and install Warden as its head.[33] It was this position as XOXW that, when Iraq overran Kuwait in August 1990, presented Warden with an unprecedented, once-in-a-lifetime opportunity to put his ideas about air campaigns into practice. Further, much as had the authors of AWPD-1 in August 1941, Warden and his like-minded colleagues seized the opportunity and made the most of it.

Deptula received similar "top cover" and support from senior officers. In early 1988, when Warden became XOXW, Deptula was a major in the Air Staff's doctrine division. Deptula's first major project in the doctrine shop was to write a response to the position espoused in a recent issue of *Military Review* to the effect that the best thing to do with air power is to hand its control over to the corps commander. This project forced Deptula to begin thinking seriously about the design and conduct of offensive air campaigns. With the help of others in the doctrine shop, including the military historian Williamson Murray, Deptula produced a paper that General Dugan liked so much that he had it published in *Military Review* under his own name.[34]

One implication of this history is that serious doctrinal thinking can prepare one to seize opportunities when they occur, as happened with both AWPD-1 and Instant Thunder. Another is that support from senior officers can also be crucial in providing access to opportunities to put one's ideas into practice. Next, it should be stressed that neither Warden's nor Deptula's thinking about air campaign was complete, much less published,

the day Iraq invaded Kuwait. Warden's notion of a modern state being composed of five concentric "rings" or "centers of gravity," with the target systems in each ring being increasingly less important or decisive as you move outward from the center ring, is nowhere to be found in *The Air Campaign*, although he was certainly talking about the concept in early 1990.[35] Similarly, Deptula's concept of the "master attack plan" or "MAP" as a means of structuring or organizing the daily air tasking order (ATO) was not invented until September 1990.[36]

There is one final relation between doctrine and war that merits mention. Accepting unpublished, unsanctioned ideas held by a few individuals as "doctrine" broadens the concept well beyond the most customarily usage of what is written in official manuals or accepted institutional practice. On this more expansive understanding, the doctrinal notions that affect combat outcomes, whether positively or negatively, encompass formal as well as informal precepts. Doctrine in this broader sense can include the past notions, new concepts, prior experiences, and "lessons learned" that individuals take to war with them about how best to conduct operations along with the contents of official publications such as *Air Force Manual 1-1*.

This expansive view of doctrine has an important corollary. Because no one goes to war with a blank mind—with John Locke's *tabula rasa* ("blank slate")—informal doctrine is inescapable. In this sense, the oft-heard refrain that doctrine is irrelevant is not only wrong, but professionally irresponsible. Like it or not, in time of war doctrine counts, and we ignore it at our peril.[37]

3. Technology and War

What about the relations between technology and war? From the standpoint of air power, the most important linkage to confront is the degree to which superior technology and weaponry can be the *guarantor* of combat success. The hypothesis that technically superior hardware *often* or *always* guarantees success in combat can be described as "technological determinism."

Has a tendency toward technological determinism been a characteristic of the U.S. Air Force? Thoughtful students of the institution have certainly acknowledged its strong, enduring commitment to the pursuit of advanced technology. In 1986 David MacIsaac began his survey of air power theory for the new edition of *Makers of Modern Strategy* with the observation that, in a field with no lack of theorists, the effects of technology and the deeds of practitioners had played greater roles than ideas; he ended the essay with the speculation that "today's primary air power theorist may be technology itself."[38] In a similar vein, Carl Builder, a long time RAND analyst and participant in Project Air Force, wrote in 1994: "The Air Force has long worshipped at the altar of technology . . . This is the catechism: If the Air Force is to have a future of expanding horizons, it will come only from understanding, nurturing, and applying technology."[39]

The reasons this catechism has taken such deep root in the U.S. Air Force are not hard to unearth. To begin with, Army Air Forces leaders had experiences during World War II that strongly reinforced the need for technical superiority. The most obvious case, of course, was the development of the atomic bomb. Its employment from B-29s not only ended the war in the Pacific but, for a time, quieted further debate about the efficacy of strategic bombing and the need for an independent American air force. Another wartime experience that underscored the importance of technological superiority in the minds of Army Air Forces leaders was the appearance, in July 1944, of German jets, particularly the Me-262. The fear of senior American air commanders in Europe at the time was that planes like the Me-262, if fielded in sufficient numbers, could "force an end to the American strategic bombing campaign."[40]

Such wartime experiences, however, are not the only reasons the institutional U.S. Air Force has been prone to technological determinism. To touch on some of the deeper reasons, armies and navies have been around since ancient times. Air forces, by comparison, only emerged about a century ago and owe their very existence to the technological developments that made heavier-than-air flight possible. The modern airman is, therefore, beholden to and dependent on advanced technology to a degree that soldiers and sailors historically were not (even if many of them—including tank drivers, submariners, naval aviators—are today as dependent on technology as Air Force fighter and bomber

crews).[41] Another reason for the U.S. Air Force's tireless pursuit of ever more advanced technology has been the ahistorical character of the institution. As a faculty member of the Air War College recently observed, the inclination of many in the Air Force officer corps to reject the relevance of history goes far to explain the institution's fixation "on technology as the key to the future."[42] If the past is viewed as unworthy of serious study, then what else is there for a "high-tech" institution beyond pursuing technology?

It is a short step from this sort of institutional concern with technological superiority to outright technological determinism, and more than a few in and around the Air Force have teetered on the brink of such determinism, if not embraced it. Consider, for instance, the following statement published in the predecessor to *Airpower Journal* by a senior Air Staff colonel in 1983: "From ancient times when the Bronze Age superseded the copper only to fall to the iron, technological superiority has most often provided the margin for victory."[43] Or take (then retired) General T. R. Milton's assertion in a 1986 issue of *Air Force Magazine* that "The entire short history of air warfare confirms that victory follows the most technically advanced adversary rather than the most heavily armed."[44]

One could protest that these statements stop a hair short of full-blown technological determinism, even if they do come awfully close. Also, they were both written a decade or longer ago, and one could object that they may not reflect current Air Force thinking. For those inclined to make such objections, it may be useful to consider Air Force Colonel Jeff Barnett's conclusion, published in early 1996, that technological advances in information, command and control, penetration, and (nonnuclear) precision are "underwriting a new aerospace approach to future war."[45] Or, even more to the point, consider the charter that authors of the *New World Vistas* attributed to the Air Force secretary and chief of staff. The Air Force Scientific Advisory Board's understanding of its charter was "to identify those technologies that will guarantee the air and space superiority of the United States in the 21st century"—a formulation that does appear to embrace technological determinism.[46] Granted, the 29 November 1994 memorandum that directed the Scientific Advisory Board to undertake the "New World Vistas" project does not *itself* explicitly embrace this outlook. Instead, the 1994 memorandum merely notes,

strongly confirming Builder's assessment, that a "high technology orientation" has always been a "fundamental part of Air Force culture."[47] Nor is it surprising that the Air Force's scientific advisory board would give preeminent importance to technological superiority. Still, it seems fair to conclude that something quite close to technological determinism resonates deeply within the Air Force's institutional psyche and worldview.

Is it in fact true, though, that superior technology *guarantees* combat success, either in the large or in the small? To answer the question in the large, we need to look no further than to the protracted air war that U.S. forces waged in Southeast Asia from 1965-1973. In this case, which side, the U.S. or its North Vietnamese foe, was technically superior in the air? This question is often difficult to answer in specific historical cases. In this particular instance, however, it is not. Which of two sides, after all, had: (1) fighters with state-of-the-art radars and beyond-visual-range (BVR) air-to-air missiles,[48] (2) a large fleet of aerial tankers with which to extend the reach of its combat aircraft, (3) as many as two hundred B-52 heavy bombers, (4) large numbers of laser-guided bombs, (5) anti-radiation missiles, or (6) airborne surveillance platforms? The answer in every case is the United States. Besides enjoying a heavy numerical preponderance in the air, the U.S. land- and sea-based air forces possessed across-the-board, pervasive technological superiority over their smaller North Vietnamese adversary. Further, so numerically and technically superior were U.S. air forces that the North Vietnamese were never able to sustain a serious challenge to American control of the air, not even in the upper "route packages" where most of the air-to-air combat between the two sides occurred. True, excepting the Navy in 1972-73, American fighters did not enjoy the highly favorable air-to-air exchange ratios in Southeast Asia achieved earlier in Korea's MiG Alley or later during Desert Storm. There was even a period in early 1968 when the North Vietnamese briefly achieved near parity in air-to-air kills against Air Force and Navy fighters operating over North Vietnam. Nonetheless, American control of the air was never seriously in doubt. Even in the spring of 1968, U.S. airmen operated large strike packages day in and day out in North Vietnamese air space, whereas North Vietnamese fighters did not once disrupt a U.S. refueling track, much less attack an American main operating base. Yet, despite across-the-board technical superiority and control of the air, the United States lost

the Vietnam War. At the end of the conflict in 1975, North Vietnamese forces overran and occupied South Vietnam. In the large, therefore, this historical case demonstrates that neither technical superiority nor even control of the air necessarily guarantees ultimate victory.

To preempt one possible misinterpretation of this conclusion, it should not be presumed that the Vietnam War in the large was air power's alone to win or lose. To suggest that American air power could have produced overall victory given the strategic circumstances in which the war was fought independent of what happened on the ground inside and adjacent to South Vietnam would surely be hubris on the part of airmen. Short of the nuclear devastation of North Vietnam—hardly a viable option for a western democracy like the United States midway through the Cold War—it is open to question whether ultimate victory was attainable for the American military as a whole. As Andrew Krepinevich argued in 1986, even an outright invasion of North Vietnam might well have failed to produce strategic success.[49] True occupation of the Hanoi-Haiphong region would have bought South Vietnam more time to become a viable nation able to defend itself. But invasion and occupation would have almost certainly been more costly in American lives while leaving the North Vietnamese with the option of guerrilla warfare in the north aimed at waiting for the U.S. to tire or else to experience a military disaster as traumatic as the French defeat at Dien Bin Phu in 1954.[50] As Mark Clodfelter, Ronald Spector, and others have argued, for the United States the Vietnam War was an optional conflict fought for limited objectives, whereas for the North Vietnamese communists it was a total war of national survival.[51] The North Vietnamese "were prepared to accept limitless casualties" while Americans were not.[52] Given these facts, the stalemate that emerged on the battlefield during 1968 favored North Vietnam in the long term.[53] Consequently, it remains open to grave doubt whether "a plausible facsimile of victory was attainable" for the United States.[54]

What about technological superiority in the small? Can superior technology at least guarantee success at the lowest tactical level of individual engagements? Again the answer is "No." The best evidence comes from historical and test data on air-to-air engagements. To start with historical combat data, combat experience going at least back to

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World War II suggests that surprise in the form of the unseen attacker has been pivotal in three-quarters or more of the kills. For example, P-38 pilot Lieutenant Colonel Mark Hubbard stressed that, in his experience over northern Europe with the U.S. Eighth Air Force, "<u>90% of all fighters shot down never saw the guy who hit them</u>."[55] Similarly, the German Me-109 pilot Erich Hartmann, whose 352 kills during World War II made him the top scorer of all time, has stated that he was "sure that eighty percent" of his kills "never knew he was there before he opened fire."[56]

Neither the shift to jet fighters for air superiority during the Korean War nor the development of infrared and radar-guided air-to-air missiles in time for U.S. involvement in Vietnam appear to have changed the basic pattern observed by Hubbard and Hartmann. U.S. fighter crews experienced some 600 air-to-air engagements in Southeast Asia from April 1965 to January 1973. These engagements produced some 190 kills against 75 U.S. losses.[57] Detailed engagement reconstructions revealed that around 80 percent of all aircrews downed—friendly as well as enemy—either were unaware of the attack, or else did not become aware in time to take adequate defensive action.[58] What historical air combat experience reveals, therefore, is that upwards of 80 percent of the time, those shot down were *unaware* that they were under attack until they either were hit or did not have time to react. A lapse or breakdown in what fighter pilots have come to term "situational awareness"—meaning "the perception of the whole picture, not only location but also likely future activity, both friendly and enemy" forces[59]—has, by a large margin, been the cause of the majority of losses in actual air-to-air combat. Indeed, the ability of human participants to develop and maintain superior situation awareness has been the driver in engagement outcomes at least four times more often than technological advantages in aircraft, avionics, or armament.

This implication of actual combat experience has been strongly confirmed by large-scale tests designed to produce statistically meaningful data about air combat. In 1977, the bulk of two major air-to-air tests were flown on an instrumented air combat maneuvering range north of Nellis Air Force Base, Nevada: the Air Intercept Missile Evaluation (AIMVAL) and the Air Combat Evaluation (ACEVAL). These tests pitted "Blue Force" F-15s and F-14s against "Red Force" F-5Es, chosen to simulate the Soviet-

built MiG-21; Cubic Corporation's air combat maneuvering instrumentation (ACMI) system provided a combat area some 40 nautical miles in diameter as well as "realtime" data on the engagements.[60] The Blue fighters were "armed" with guns, short-range infrared (IR) missiles, and the medium-range, radar-guided AIM-7F Sparrow missiles; Red ordnance, by contrast, was limited to guns and IR missiles. AIMVAL sought to assess the operational utility of five existing and proposed IR missile concepts.[61] ACEVAL explored the factors affecting engagement outcomes when multiple aircraft are involved, with force size, force ratio, and initial ground-controlled-intercept (GCI) condition (Red advantage, neutral, or Blue advantage) as the primary test variables.[62] To give a feel for the scale of these tests, AIMVAL's test matrix included Blue-versus-Red force ratios of 1-v-1 (one F-15 or F-14 versus one F-5E), 1-v-2, 2-v-2, and 2-v-4, and called for 540 valid engagements involving 1,800 sorties.[63] ACEVAL's test matrix added 2-v-1, 4-v-2, and 4-v-4 trials to the four force ratios used in AIMVAL and required a total of 360 valid engagements involving 1,488 sorties.[64]

The results of AIMVAL/ACEVAL were highly controversial at the time. At the core of the debate was the fact that "superior" Blue fighters, avionics, and missiles had not dominated Blue-Red exchange ratios nearly as much as had been expected (except in certain "test bins" such as isolated 1-v-1 trials). Not widely noted in 1977 and 1978 was the disconnect between these expectations and past historical experience. If superior Blue technology had proven as dominant in AIMVAL/ACEVAL as many expected, then these tests would have also revealed the irrelevance of past combat experience, especially its implication that situation awareness explained why people were shot down four times out of five. So dramatic a break with combat experience would have been a watershed. However, by 1979 more thoughtful reflection on AIMVAL/ACEVAL began to suggest that it was not quite time to reject previous air combat history. As Lieutenant Colonel "Shad" Dvorchak wrote in a special 1979 issue of the *Tactical Analysis Bulletin*, in AIMVAL incremental hardware advantages had tended to wash out in the long run as opponents adapted; similarly, in ACEVAL, human interactions had been five times as influential on outcomes as test variables like force ratio or the initial GCI condition.[65]

Nevertheless, it was still possible to argue in 1980 that technological dominance of engagement outcomes would materialize in the future. Throughout AIMVAL and ACEVAL, visual identification prior to weapon employment had been a mandatory rule of engagement and the only radar missile allowed had been the AIM-7F Sparrow.[66] It was easy to conclude that these constraints had biased both tests against effective BVR (beyond visual range) employment.

The issue of whether widespread use of BVR missiles would finally enable technology to dominate engagement outcomes was settled by the Advanced Medium Range Air-to-Air Missile (AMRAAM) Operational Utility Evaluation (OUE). Conducted in McDonnell Douglas flight simulators starting in 1981, this test gave Blue fighters a medium-range, radar-guided AMRAAM, and half the non-excursion trials were run with BVR rules of engagement. The AMRAAM OUE test matrix called for over 1,200 engagements involving around 10,000 simulator sorties.[67] Instead of a small cadre of specially selected aircrew, AMRAAM OUE participants were drawn from operational units in the U.S. Scenarios included fighter-sweep situations (2-v-2 and 2-v-4) as well as trials in which the Blue fighters faced Red fighters escorting strike aircraft (2-v-4 + 4, 2-v-2 + 6, and 4-v-4 + 4). About half the trials were excursions from the standard sweep and combat air patrol scenarios.

The natural expectation was that in the BVR trials at least, Blue hardware advantages would drive engagement outcomes. Actual test results, however, proved otherwise. As in both historical combat experience and AIMVAL/ACEVAL, situation awareness proved to be "the single most important factor affecting engagement outcomes."[68] For both sides, being aware of adversary weapons envelopes and keeping outside them to avoid being "shot," while trying to maneuver adversaries into their own weapons envelopes, proved as important and dominant as it had been in ACEVAL.

To avoid misinterpretation, the *statistical* dominance of AMRAAM OUE engagement outcomes by situation awareness should not be construed as implying that hardware—including aircraft performance, avionics, and missile capabilities—counted for nothing. To the contrary, superior Blue hardware conferred building blocks or baseline elements of advantage that the Red side had to work hard to overcome and, in the

aggregate, Blue hardware advantages were reflected in superior Blue exchange ratios. To put the point somewhat more vividly, Blue's hardware advantages conferred tactical options and possibilities not unlike being able to maneuver in three dimensions while the adversary is limited to only two. Statistically, though, the outcome of any given engagement depended on very small differences here or there across a large set of interrelated human and hardware factors, and the dominant of these factors, by far, was situation awareness. Thus, what has been termed technological determinism is no more viable in the small than in the large. Indeed, the combined data from combat experience and large tests such as the AMRAAM OUE provide *compelling* refutation of technological determinism in at least one, technologically intensive area of air warfare.

What does this implication suggest about the relations between technology and war? Clearly, the connections between technology and war are neither simple nor straightforward. Yes, superior technology is important, especially for a western democracy concerned to minimize the sacrifices its sons and daughters may have to make in future wars. General Hap Arnold's observation in November 1944 that the United States will "continue to fight mechanical rather than manpower wars" because Americans find personnel losses so distasteful is, if anything, even more valid today than it was then.[69] Still, superior technology does not and cannot guarantee success, either in the large or in the small. The successful application of military hardware in the pursuit of political objectives requires more than technological superiority. As General Charles Donnelly wrote in the introduction to John Warden's *The Air Campaign*: "It is possible for an air force to have absolutely superior forces—numerically and qualitatively—and lose not only the air war but the entire war."[70] Whether Air Force officers view this proposition as common sense, a doctrinal precept, or a generalization about twentieth-century warfare that is well supported empirically, it needs to be kept constantly in mind as a counterweight to the institution's legitimate pursuit of technological superiority. While there remains an element of truth to the thesis that superior weapons *favor* victory, they do not, and cannot, guarantee it.[71]

4. Doctrine and Technology

What about doctrine and technology? What are some of the elementary relations between doctrinal precepts and hardware that may help to minimize confusion as we try to think about the future of war in the post-Cold war era? One elementary point that has, at least occasionally, been neglected in the Air Force's enthusiasm for advanced technology is the gap between *technical feasibility* and *operational utility*. That a given capability is technically feasible does not always mean that it is operationally useful in the demanding world of actual combat. The limited number of BVR missile kills attained by American and Israeli fighter crews from the early 1960s through the early 1980s offers an illuminating case in point.

The advent of radar-guided missiles for air-to-air combat with sufficient range to be fired BVR on a fighter with a powerful enough radar to exploit such a missile can be dated from the early 1960s when the initial U.S. Navy variants of F-4 Phantom II, equipped with the AIM-7 Sparrow III missile[72] and the AN/APQ-72 radar, entered operational service. Since the Marine Corps had embraced the F-4 from the outset, and because Robert McNamara imposed the Phantom II on the Air Force in 1962,[73] all three services were all reequipping their fighter, interceptor, and attack squadrons with either F-4Cs (the Air Force variant) or F-4Bs (the Navy-Marine model) by the eve of American military involvement in Vietnam. By the eve of the Yom Kippur War in October 1973, the Israeli Air Force (IAF) also had F-4s and Sparrows. Beginning in late 1969, the first F-4Es were exported to Israel,[74] and, by October 1973, the IAF had acquired nearly 130 Sparrow-equipped Phantom IIs.[75] As a result, over the course of the Vietnam War American air forces were increasingly equipped with fighters technically able to employ BVR missiles in aerial combat, and the IAF had this capability in both 1973 and 1982.

The salient fact about the technical capability to fire from beyond visual range was simply this: it was very seldom exploited successfully in actual air combat either by American aircrews in Southeast Asia during 1965-1973, or by Israeli aircrews in the Mideast in the conflicts of 1973 and 1982. From the beginning of Operation Rolling Thunder in March 1965 to the end of U.S. air operations against North Vietnam in Janu-

ary 1973, only two beyond-visual-range kills were officially recorded out of a reported 597 Sparrow firings.[76] The Yom Kippur War of 6-24 October 1973 was a much shorter conflict, but the air-to-air combat was intense. During the eighteen days of fighting, the Israeli Air Force claimed to have downed some 265 Egyptian and 130 Syrian planes.[77] Yet, despite the large amount of air-to-air combat, Israeli F-4s only fired twelve AIM-7 Sparrows in anger and claimed a single BVR kill.[78] The seven days of intense air combat associated with Israel's June 1982 invasion of Lebanon tell a similar story. By the time Operation Peace for Galilee began, the Israelis had added F-16s and Sparrow-equipped F-15s to their inventory. During the major air battles between Israeli and Syrian fighters that occurred over the Bekaa in June 1982, the IAF split air superiority duties between their F-15s and F-16s, the latter being armed only with an internal gun and short-range, infrared missiles. While the Israelis are thought to have downed 80 Syrian MiG-21s, MiG-23s, and SU-20s (plus five helicopters), only 23 AIM-7s were fired and, as in October 1973, only a single BVR kill claimed.[79] In sum, out of some 632 combat firings of radar-guided missiles from 1965 to 1982 by U.S. and Israeli aircrews, *only four beyond-visual-range kills* were officially recorded.

Attempts to achieve BVR shots by American and Israeli aircrews during this period appear to have been similarly limited. Only about 10 percent of the 632 firings occurred at distances beyond five nautical miles.[80]

Why was the exploitation of the *technical* capability to fire from beyond visual range so rare? Why were there not considerably more BVR shots and kills? The reasons that the AIM-7 had so little success as a BVR weapon throughout this period were many and complex.[81] The overriding constraint, however, was not a technical one but a matter of *compelling human preference*. American and Israeli fighter pilots were, understandably, reluctant to shoot BVR unless they could be highly confident, if not virtually certain, that the target on the radar scope would not turn out to be a friendly aircraft. This natural reluctance to risk air-to-air fratricide was often reinforced by stringent rules of engagement that required positive target identification prior to firing.[82] Consequently, beyond-visual-range kills were, for the most part, only feasible under very carefully controlled conditions in which special equipment for identifying friend from foe was available and

accompanying procedural safeguards (rules of engagement) could be satisfied under actual combat conditions.

Not until the Persian Gulf War of 17 January-28 February 1991 did the marriage of equipment, including by this time E-3A Airborne Warning and Control System (AWACS) aircraft, and operational circumstances permit a significant portion of the engagements that resulted in ordnance kills (15 of 38 total Coalition kills) to begin with BVR shots.[83] But as impressive as this performance was, a razor-thin margin between successful "kills" of enemy aircraft and the tragedy of fratricide remains a stubbornly persistent feature of modern air warfare. Missiles of all sorts—air-to-air, surface-to-air, and air-to-surface—have grown ever more reliable and lethal. Yet combatants must still make split-second shoot/no-shoot decisions in order to be effective, and, under the extraordinary pressures of combat environments, those decisions remain open to fatal error. The tragic downing of two U.S. Blackhawk helicopters by a pair of U.S. F-15Cs in the "no-fly zone" over northern Iraq on 14 April 1994, which resulted in the deaths of all 26 people on board the Blackhawks, goes far to illustrate the difficulties of *reliably* separating friend from foe in beyond-visual-range missile engagements.

The historical reluctance of American and Israeli fighter crews to risk BVR shots in actual combat can, of course, be viewed as a technological problem in the sense that ongoing advances in sensors and information systems ought to provide improved means of identifying both friends and foes. The Joint Tactical Information Distribution System (JTIDS), which has been recently declared operational on one squadron of U.S. Air Force F-15s, represents a step in this direction within the realm of air-to-air combat. U.S. Army efforts since the 1991 Persian Gulf War to begin digitizing future battlefields constitutes another. Given the increasing reliability and lethality of air-to-air, air-to-surface, and surface-to-surface precision weaponry, the imperative for U.S. forces to be able to separate friends from foes with very high reliability in real time is clear, and there is every reason to expect that technological advances can provide significant improvements in American technical capabilities to do so.

Nonetheless, the great reluctance of U.S. and Israeli fighter crews to exploit their technical ability to take BVR shots from 1965 through 1982 illustrates the power of na-

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tional values and service cultures to constrain military operations regardless of fielded capabilities. Prior to Desert Storm, the Joint Forces Air Component Commander, (then) Lieutenant General Charles Horner, imposed stringent rules of engagement for BVR shots that very few Coalition fighters could satisfy on their own.[84] He also made it crystal clear before and during the conflict that he would not tolerate Blue-on-Blue fratricide in the air. The resulting constraint was fundamentally a *doctrinal* one. As in Southeast Asia and the Middle East during 1965-1982, this doctrinal constraint limited the capability of friendly forces to exploit fully technical capabilities resident in fielded equipment, and rightly so. Technical feasibility, as people are prone to forget in the pursuit of superior weapons, is not the same as operational utility.

The other side of this proposition is that doctrinal myopia can also *prevent* the full exploitation of technically superior weaponry. A good illustration is provided by the very different results that laser-guided bombs (LGBs) are perceived to have achieved in Southeast Asia as compared with the Persian Gulf War. In Vietnam, LGBs were a historical footnote, mostly of interest to Fighter Weapons School instructors tasked with teaching others how to employ them. In Desert Storm, by contrast, the combination of precision weapons and, in the case of the F-117, stealth has been widely billed as tantamount to a revolution in warfare. As Colonel John Warden has argued, Desert Storm was "revolutionary" in the "sense of the very few number of bombs that were required to achieve an enormous amount of very, very focused, precise destruction."[85] How might this apparent discrepancy be explained?

Air Force interest in laser-guided bombs dates from 1958 when the Limited War Committee of the Woods Hole Summer Study Group began exploring whether monochromatic or single-frequency laser (light amplification by simulated emission of radiation) light could be used for guidance. In 1960, researchers demonstrated a practical method for generating and projecting laser light. Developmental work on laser guidance began soon thereafter.

The Air Force's first laser-guided bomb program was started in 1965, and the initial combat experiments with 750-pound (Mark-117), Paveway I LGBs were carried out during the spring of 1968 by F-4s from the 8th Tactical Fighter Wing (TFW) at Ubon in

southern-most North Vietnam (Route Package I).[86] By September 1968, combat experience indicated that about half of the 2,000-pound (Mark-84) LGBs could be expected to hit within 20 feet of the aiming point.[87]

This early success with LGBs led to growing combat use of laser-guided bombs through the end of large-scale American combat involvement in the Vietnam War in early 1973. Perhaps the most famous accomplishments of "smart" bombs during this period were the dropping of the Thanh Hoa and Paul Doumer bridges in the spring of 1972 as part of Operation Linebacker I (April-October 1972).[88] While precision targets other than bridges were also attacked with LGBs during Linebacker I, including thermal power plants, the bulk of the employment through the end of the Vietnam War appears to have been against lines-of-communications choke points, especially bridges. For example, between 6 April and the end of June 1972, laser bombers from the 8th TFW alone were credited with destroying 106 bridges.[89] In this sense, the operational concept, or employment doctrine, for LGBs did not differ greatly from that underlying the use of radio-controlled Razon and Tarzon bombs against bridges during the Korean War.[90]

This fact probably goes far to explain why the advent of laser-guided bombs in Southeast Asia was viewed by most observers as, at best, a tactical advance. The tactical utility of these weapons during the final years of the war in hitting point targets was clear. Individual bridges that had survived repeated attacks during Rolling Thunder (and cost a number of losses to North Vietnamese ground-based air defenses in the process) were dropped in 1972 by one or two strike package of laser bombers. Yet, for all their tactical success, LGBs were not widely perceived during the decade after Vietnam to have signaled any major breakthrough or profound change in aerial warfare. Postwar surveys of U.S. air operations in Southeast not only offered little premonition of the much larger role that precision weapons would play in Desert Storm,[91] but largely failed to anticipate the post-Desert Storm view that "Precision Air Weapons Have Redefined the Meaning of Mass."[92]

Why was the potential of precision air munitions so hard for airmen to foresee during the late 1970s and early 1980s? Part of the answer undoubtedly lies in the operational limitations exhibited by Vietnam-era precision weapons such as the Paveway I

LGBs. They had to be released so as to fall into the relatively small cone over the aim point within which the seeker could detect reflected laser illumination constrained delivery tactics. Further, the aircrew in the designating aircraft had to rely on "Mark I eyeballs" to see the aim point in order to illuminate it, which limited laser bombing to daylight hours during periods of relatively good visibility.[93] After the Vietnam War, as American airmen began thinking anew about conventional air operations in central Europe, this particular feature of laser-guided bombs seemed especially limiting given the low ceilings and limited visibility typical over East and West Germany and the Low Countries during certain portions of the year.

Of course, between 1973 and 1991 improvements were made to laser-guided bombs and the associated designation equipment needed to illuminate aim points. Although the Paveway II kits slightly increased the cone-shaped volume or "basket" over the target into which an LGB had to be dropped by the releasing aircraft for the bomb to "see" the laser illumination, the Paveway III low-level laser-guided bomb (LLLGB) expanded release baskets many-fold by adding an autopilot that would enable the bomb to fly itself into the basket.[94] The other major upgrade to Vietnam-era laser-bombing capabilities was the fielding during the 1980s of PAVE TACK, an infrared imaging targeting pod initially deployed on the F-111F. By mounting the sensor in a rotating turret, PAVE TACK enabled the laser spot to be kept on the aim point through a wide range of aircraft maneuvers, and the ability to look to the rear permitted imaging to be maintained to weapons impact.[95] In addition, infrared imaging permitted precision attacks to be conducted at night.

On the one hand, these improvements in U.S. laser-bombing capabilities from 1973 to 1991 were far from trivial. They gradually began to overcome some of the more glaring limitations of the LGBs employed during the Vietnam War. On the other hand, they hardly seem tantamount to a revolutionary advance in warfare, not even when the stealth of the F-117 is taken into account. After all, even by Desert Storm standards, the quantities of laser-guided bombs expended during the final years of the Vietnam War were large. The total number of LGBs dropped by U.S. forces in Southeast Asia during fiscal years 1970-1973 was 27, 507 kits, with roughly another one thousand expended in

prior years for a total of 28,508.[96] This total of 28,508 LGBs expended in Southeast Asia is three times greater than the 9,342 dropped by U.S. air forces during 43 days in January and February 1991. Even if one adds the roughly 1,200 laser-guided munitions known to have been dropped by British, French, and Saudi aircraft, the Coalition total for laser-guided bombs and missiles probably does not exceed 11,000 weapons.[97] Yet it is Desert Storm that marks the real "coming of age" of precision bombardment in most people's minds, including that of John Warden, one of the conceptual architects of the Coalition air campaign.

Is Warden mistaken? This author thinks not, but the reason lies more in differences in concepts and doctrine from Vietnam to Desert Storm rather than in technological improvements. The Gulf War was the first campaign in history in which PGMs in general, and LGBs in particular, directly influenced effectiveness at the operational and strategic levels of a theater conflict. One obvious example is the success of LGBs in destroying Iraqi aircraft in hardened shelters, thereby precipitating efforts to move the most capable Iraqi aircraft to "sanctuary" in Iran. Another example is the success of LGBs during the second half of Desert Storm in separating Iraqi armored crews from their vehicles in the Kuwait theater of operations, thereby doing much to ensure that Coalition casualties would be unprecedentedly low when Coalition ground forces engaged Iraqi Republican Guard units such as the Tawakalna mechanized and Madinah armored divisions. Yet another (and even more fundamental) example is the conscious use of precision and stealth to enable Coalition air planners to pursue functional effects against a number of target systems more or less in parallel. The decision to leverage precision and stealth to permit the parallel attack of multiple target systems from the opening minutes of the campaign was a fundamental conceptual change from the one-target-system-at-a-time approach generally used in World War II, Korea, and Vietnam. By contrast, the use of LGBs in Southeast Asia was largely a tactical matter. Unguided weapons had enjoyed scant success in dropping heavily defended bridges without the expenditure of inordinate numbers of sorties; in the case of the Thanh Hoa, even hundreds of sorties and a number of aircraft losses had failed to eliminate the target on any permanent basis. LGBs provided a means of doing so with much increased efficiency, but that greater efficiency did

not exert any obvious operational or strategic impact on the overall outcome of the conflict. Hence, there is a legitimate sense in which precision-guided bombs, especially LGBs, came of age in 1991, and the difference lay first and foremost in a doctrinal change.

Doctrine, then, may not only constrain the operational utility of technically feasible capabilities for the very best of reasons, as in the case of BVR missiles, it can also hobble technically useful ones, as in the case of LGBs. To generalize only slightly, the trick is to get a better "fit" than the opponent between hardware, doctrine and operational concepts, and, to make things work in the real world, appropriate organizational adaptations. One of the best examples in this century of one side getting the "fit" far closer to "right" than the opponents is surely the Germans' campaign against France and the Low Countries in May 1940. The Allies, it turns out, possessed a numerical edge of approximately 1.3-to-1 in tanks, and many of their armored vehicles possessed superior protection and armament to the Germans' tanks.[98] Moreover, at the outset of the May 1940 campaign, the Allies had force-ratio advantages of around 1.2-to-1 in manpower, a slight edge in divisions (1.03-to-1), and, from Luxembourg to the Swiss border, the French had completed the Maginot Line; only in total aircraft and antiaircraft artillery did the Allies face substantial disadvantages at the theater level.[99] In the end, however, these qualitative and quantitative advantages failed to save the western Allies from one of the most stunning military defeats in modern military history. In a nutshell, the Germans had evolved sound concepts for mobile, combined-arms warfare and had trained their combined-arms units to execute their operational doctrine. They had, in short, achieved a much better "fit" between military hardware, concepts and doctrine, and organizational arrangements.

The larger lesson is clear. Technology is important, but so is doctrine. Even more important is a harmonious fit between the two. Developing a better fit than the adversary involves, as Andy Marshall has repeatedly emphasized since 1989, doctrine development and organizational adaptation as well as technological progress.

5. Implications for the Future

The widely discussed hypothesis of an emerging "revolution in military affairs" suggests that much about war may change in the decades ahead. It seems fairly clear that, in the not-too-distant future, U.S. surveillance systems are going to be able to collect and disseminate in "near-real time" vastly more information relevant to military operations than U.S. commanders, operators, and planners have had in the past. Concurrently, the fielding in quantity of through-weather precision weapons with affordable per-round costs, notably the Joint Direct Attack Munition (JDAM) now estimated at less than $20,000 a kit, means that in the years ahead it will become possible to shift to largely precision strike campaigns. Indeed, it seems difficult to imagine why the U.S. would choose to conduct a major air campaign after 2010 in which, as in Desert Storm, more than 90 percent of the air-to-surface and surface-to-surface weapons employed are "dumb," unguided rounds. If one adds to these modest and foreseeable changes in the means of combat nothing more than the appearance of first-generation, remotely piloted strike platforms, it is not difficult to anticipate major changes in both Air Force doctrine and warfighting organizations.

As our exploration of the relations between doctrine, technology and war indicates, though, the central problem the U.S. military needs to solve in such a period of change does not lie in technological development per se. Instead the key to the future probably lies in the "intellectual task" of getting a better "fit" between advanced hardware, concepts and doctrine, and organizations than the opponent. While one clearly prefers to have superior technology if at all possible, the most pressing problem in coping with the kinds of changes likely to lie ahead "is to be the first, to be the best in the intellectual task" of "developing appropriate concepts of operation, making the organizational changes, and creating the doctrine and practices that fully exploit the available technologies."[100] The choice is up to us and, within the metaphor of the *Blitzkrieg* in May 1940, one would definitely prefer to be the Germans rather than the western Allies.

Consequently, the thrust of this essay has been to try to place such changes in a broader context by recalling fundamental relations between doctrine, technology, and

war—relations that, arguably, have withstood the test of time throughout the twentieth century, if not longer. To reiterate the main points: doctrine really does count; getting doctrine wrong can lead to military disaster; doctrine encompasses more than what is written in official manuals; superior technology in and of itself does not, and cannot, guarantee military success, either in the large or in the small; technical feasibility is not equivalent to operational utility; indeed doctrine rooted in societal values may rightly constrain the employment of fielded capabilities; and, finally, old doctrine seldom makes the most of new hardware, as the case of LGBs so aptly illustrates.

At this stage, a reasonable speculation would appear to be that these sorts of conclusions, if understood in historical context, may begin to sketch the outlines of a more empirically rigorous foundation for future doctrine than it has generally enjoyed in the past. The issue of the long-term future of Clausewitzian friction offers an illuminating example of how such a foundation may help us to avoid confusing ourselves in an era of considerable change. Some U.S. military officers who have begun to grapple with the prospective changes in warfighting that may lie ahead have begun to argue that foreseeable advances in surveillance and information technologies will sufficiently lift "the fog of war" to enable future American commanders to "see and understand everything on a battlefield."[101] Advances in sensor technologies and information systems may (or will) enable the side exploiting them more effectively to eliminate its "fog of war" while turning the opponent's into a "wall of ignorance."[102]

Implicit in this view is the presumption that "knowing everything that is going on" in a volume of battlespace is a problem that technological advances will eventually "solve" once and for all.[103] However, driving one's own friction to zero while, simultaneously, rendering the enemy's effectively infinite is *not*, at its core, a technical problem. In the first place, even in an "information-rich" environment, there is only so much that any human can absorb, digest, and act upon in a given period of time. The greater the stress, the more data will be ignored, noise mistaken for information, and information misconstrued, and the greater will be the prospects for confusion, disorientation, and surprise. Second, the spatial and, especially, temporal distribution of information relevant to decisions in war means that some key pieces will be inaccessible at any given time and

place, just as they are not in market economies or biological evolution. Third, the empirical fact of nonlinear dynamics, when coupled with the unavoidable mismatches between reality and our representations of it, reveal fundamental limits to prediction, no matter how much information and processing power technological advances may one day place in human hands.[104] In short, friction reinterpreted in modern terms gives every indication of reflecting *structural* features of human cognition and combat processes. If so, then technological progress may be able to manipulate friction, but certainly not eliminate its potential to dominate combat outcomes.

The deeper point of this example is, of course, that there are aspects of war that technology is unlikely to affect other than on the margin, and doctrine needs to be fully, constantly cognizant of these more enduring, structural aspects of war and combat processes. As Eliot Cohen has observed: "The simple and brutal fact remains that force works by destroying and killing."[105] Similarly, Colin Gray has recently produced a whole list of things about war that are unlikely to change in the years ahead, including the central role of geopolitical conflict in international politics and the absence of change in human nature.[106] These are things that the writers of future doctrine ought not neglect.

Nevertheless, doctrine should neither be chiseled in stone nor viewed as if it has been. We should approach it as a "work in progress," always open to modification or revision on the basis of evidence from the only test that matters: actual combat. Again, the architects of AWPD-1 and the Desert Storm air campaign were able to seize once-in-a-lifetime opportunities because they had grappled with doctrine long enough and hard enough to be prepared to do so. That requirement did not end with the Gulf War or even with Deliberate Force.

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[1] The views expressed in this paper are the author's. They do not represent the views of the Air War College, the Air University, the United States Air Force, the Department of Defense, or the Northrop Grumman Corporation.

[2] James Digby and J. J. Martin, "On Not Confusing Ourselves: Contributions of the Wohlstetters to U.S. Strategy and Strategic Thought," *On Not Confusing Ourselves: Essays on National Security Strategy in Honor of Albert & Roberta Wohlstetter*, ed. Andrew W. Marshall, J. J. Martin, and Henry S. Rowen (Boulder, Colorado; Westview, 1991), p. 3. Illustrative of Albert Wohlstetter's insistence on clear thinking was his 1975 article "Optimal Ways to Confuse Ourselves," which criticized the "muddled thinking of proponents of the action-reaction theory of the strategic 'arms race,' exposing their inconsistencies and the failure of this theory to accord with the facts" (*ibid.*). Another example of his intellectual clarity was the evolutionary approach he took to what began systems analysis. As Andy Marshall has noted, in the early

1950s Albert Wohlstetter was one of the first to lead and manage large studies of alternative systems or programs. Wohlstetter's greatest contribution to such studies, in Marshall's view, was his flexible approach: Wohlstetter "started with a few alternatives to the existing plan or program and as the study went on he evolved improved alternatives. He was also less rigid than had been the practice in setting down the criteria, the objective functions, the measures of effectiveness at the beginning of the study and simply sticking with them. His evolutionary approach developed additional criteria and tests of performance as more understanding of the problems and the issues emerged." (Andrew W. Marshall, "Strategy as a Profession for Future Generations," *On Not Confusing Ourselves*, p. 306).

[3] Elting E. Morison, *Men, Machines, and Modern Times* (Cambridge, Massachusetts: MIT Press, 1966), p. 36.

[4] The author owes a great intellectual debt to Thomas Fabyanic for the discussion of interwar Army Air Corps doctrine in this section. In the late 1970s, Colonel Fabyanic began giving a doctrinal presentation to successive Air War College classes that opened with a vivid account of the second Schweinfurt raid in October 1943. About a decade later, when Fabyanic could not give the lecture due to other commitments, the author inherited the presentation and gave it to several Air War College classes.

[5] Major General Haywood S. Hansell, Jr., *The Air Plan That Defeated Hitler* (Atlanta, Georgia: Higgins-McArthur/Longino and Porter, 1972), p. 15.

[6] Quoted in Robert Frank Futrell, *Ideas, Concepts, Doctrine*, Vol. I, *Basic Thinking in the United States Air Force 1907-1960* (Maxwell AFB, Alabama: Air University Press, December 1989) p. 64.

[7] Quoted in Lieutenant Colonel Thomas A. Fabyanic, "Strategic Air Attack in the United States Air Force: A Case Study," Air War College Report No. 5899, April 1976, p. 31. The cited passage from the 1935 bombardment text referred specifically to the case in which opposing fighters were "assumed to possess an overwhelming superiority in all factors influencing air combat" (*ibid.*).

[8] Geoffrey Perret, *Winged Victory: The Army Air Forces in World War II* (New York: Random House, 1993), p. 28; Fabyanic, "Strategic Air Attack in the United States Air Force," p. 30; and, David MacIsaac, "Voices from the Central Blue: The Air Power Theorists," *Makers of Modern Strategy: from Machiavelli to the Nuclear Age*, ed. by Peter Paret with Gordon A. Craig and Felix Gilbert (Princeton, New Jersey: Princeton University Press, 1986), p. 634.

[9] Perret, *Winged Victory*, p. 246; Roger A. Freeman with Alan Crouchman and Vic Maslen, *Mighty Eighth War Diary* (New York & London: Jane's, 1981), p. 9.

[10] Fabyanic, "Strategic Air Attack in the United States Air Force," p. 65.

[11] Not everyone embraced the doctrine invincibility. For example, in August 1941 then Lieutenant Colonel Clayton Bissell's comments on AWPD-1 stressed the need for an escort fighter (Miscellaneous papers for AWPD-1, Air Force Historical Research Center, Maxwell AFB, Alabama, 145.82-1, Part 3, p. 1). Similarly, in September 1942, General Carl A. Spaatz also expressed concerns over Eighth Air Force's ability to conduct daylight bombing in the face of German air superiority (Fabyanic, "Strategic Air Attack in the United States Air Force," pp. 69-70).

[12] Quoted in Bernard Boylan, "Development of the Long-Range Escort Fighter," USAF Historical Study No. 136, Air University, Maxwell AFB, Alabama, September 1955, pp. 68 and 265. At this point, both Eaker and his immediate superior in Europe, Carl Spaatz, were convinced that "once they could mount raids with large numbers of B-17s the bombers would have such massed firepower they would be able to defend themselves on the deepest raids into the Third Reich" (Perret, *Winged Victory*, p. 246).

[13] At this stage of the war, Eighth's escort fighters could only penetrate about 160 miles into enemy territory; by comparison, Schweinfurt involved a penetration of some 320 miles (Major General William E. Kepner, *Eighth Air Force Tactical Development: August 1942-May 1945* (England: Eighth Air Force and Army Air Forces Evaluation Board, 9 July 1945), p. 116).

[14] James Parton, *"Air Force Spoken Here": General Ira Eaker and the Command of the Air* (Bethesda, Maryland: Adler & Adler, 1986), pp. 188-200, 222, 279, 311, and 316-320.

[15] Freeman, *Mighty Eighth War Diary*, pp. 120-133; Wesley F. Craven and James L. Cate, *The Army Air Forces in World War II*, Vol. II, *Europe: Torch to Pointblank, August 1942 to December 1943* (Chicago: University of Chicago, 1949), pp. 849-850; and, "Statistical Summary of Eighth Air Force Operations: European Theater, 17 August 1942—8 May 1945," Air Force History Office 520.308A, p. 14. To dispatch

the "magical 300 heavies," Eighth needed at least 800 bombers in theater (Parton, *"Air Force Spoken Here"*, pp. 290-291). The average number of bombers assigned to Eighth in October 1943 was 1,000, of which 763 were "on hand" in tactical units, and only 535 of the "on hand" heavies were "fully operational" ("Statistical Summary of Eighth Air Force Operations," p. 14).

[16] Craven and Cate, *The Army Air Forces in World War II*, Vol. II, p. 699. Line bomber crews who participated in unescorted, deep-penetration missions like the second American attack on the ball-bearing plants at Schweinfurt have tended to remain puzzled and bitter right down to the present day. See, for example, Elmer Bendiner, *The Fall of Fortresses: A Personal Account of the Most Daring—and Deadly—American Air Battles of World War II* (New York, New York: Putnam, 1980), pp. 227-239; also George C. Kuhl, *Wrong Place! Wrong Time! The 305th Bomb Group & the 2nd Schweinfurt Raid: October 14, 1943* (Atglen, Pennsylvania: Schiffer, 1993), pp. 247-250. For Eaker's side of the argument as articulated by a member of his wartime staff in England, see Parton, *"Air Force Spoken Here"*, pp. 327-328. Parton's assessment specifically challenges the conclusions drawn by Arthur B. Ferguson in Chapter 21 ("The Autumn Crisis"), Volume II, of Craven and Cate's *The Army Air Forces in World War II*.

[17] Williamson Murray, *Strategy for Defeat: The Luftwaffe 1933-1945* (Maxwell Air Force Base, Alabama: Air University Press, 1983), p. 226.

[18] Craven and Cate, *The Army Air Forces in World War II*, Vol. II, p. 707

[19] Kepner, *Eighth Air Force Tactical Development*, p. 116.

[20] Craven and Cate, *The Army Air Forces in World War II*, Vol. II, p. 717.

[21] Alexander S. Cochran, Lawrence M. Greenberg, Kurt R. Guthe, Wayne W. Thompson, and Michael J. Eisenstadt, *Part I: Planning* in *Gulf War Air Power Survey*, Vol. I, *Planning and Command and Control* (Washington, DC: U.S. Government Printing Office, 1993), pp. 223 and 230.

[22] Department of Defense, *Conduct of the Persian Gulf War Pursuant to Title V of the Persian Gulf Conflict Supplemental Authorization and Personnel Benefits Act of 1991 (Public Law 102-25)* (Washington, DC: Government Printing Office, April 1992), pp. 313-317; Thomas A. Keaney and Eliot A. Cohen, *Revolution in Warfare? Air Power in the Persian Gulf* (Annapolis, Maryland: Naval Institute Press, 1995), pp. 67-69, 72, 92-93, and 102-103; and, Central Intelligence Agency, Office of Imagery Analysis, "Operation Desert Storm: A Snapshot of the Battlefield," IA 93-10022, September 1993.

[23] For an informed and clear account of the ideas and concepts underlying the Desert Storm air campaign, see Colonel David A. Deptula, "Firing for Effect: Change in the Nature of Warfare," paper presented at the Air National Guard long-range planning conference, Reno, Nevada, 3 November 1994; in August 1995, the Aerospace Education Foundation published a version of Deptula's essay as part of its Defense and Airpower Series.

[24] See, for example: Cochran, et al., *Part I: Planning* in *Gulf War Air Power Survey*, Vol. I, *Planning and Command and Control*; Colonel Richard T. Reynolds, *Heart of the Storm: The Genesis of the Air Campaign against Iraq* (Maxwell AFB, Alabama: Air University Press, January 1995); and, for context, Daniel T. Kuehl, *Airpower Journal*, Spring 1996, pp. 121-123.

[25] Cochran, et al., *Part I: Planning* in *Gulf War Air Power Survey*, Vol. I, *Planning and Command and Control*, p. 226; Reynolds, *Heart of the Storm*, pp. 133-134.

[26] Reynolds, *Heart of the Storm*, p. 232.

[27] *Ibid.*, p. 229.

[28] *Ibid.*, pp. 39-45.

[29] Colonel Edward C. Mann III, *Thunder and Lightning: Desert Storm and the Airpower Debates* (Maxwell AFB, Alabama: Air University Press, April 1995), pp. 177 and 179.

[30] After the Gulf War, the present author did encounter one Air Force intelligence officer who had served in Riyadh with CENTAF during Desert Storm and who argued vehemently that any dozen or so Air Force officers would have selected more or less the same campaign concept actually executed. This viewpoint seemed to be predicated on the notion that air campaigns are *uniquely* determined by political objectives and target lists. Given the latitude with which the military has always been able to interpret objectives, the present author has never been able to see the logic of the view that objectives and targets dictate one and only one campaign concept.

[31] Colonel John A. Warden III, "The Air Campaign," February 1986, p. vi.

[32] Colonel John A. Warden III, *The Air Campaign: Planning for Combat* (Washington, DC: National Defense University Press, 1998), p. xxiii.

[33] Lieutenant General Michael J. Dugan, "The Air Campaign," memorandum to "All Officers DCS Plan & Operations," 15 November 1988; John A. Warden, interview notes taken by Thomas A. Keaney and Barry D. Watts, Executive Office Building, Washington, DC, 21 February 1992, p. 1.

[34] General Michael J. Dugan, "Air Power: Concentration, Responsiveness and the Operational Art," *Military Review*, July 1989, pp. 12-21. By the time this article appeared, Dugan was the commander of U.S. Air Forces in Europe. Murray was a military historian who was doing reserve time in the doctrine shop and helped Deptula draft "Air Power: Concentration, Responsiveness and the Operational Art."

[35] Barry D. Watts, personal notes from conversation with John Warden, 26 January 1990.

[36] David Deptula, marginalia on draft of Chapter 7, Gulf War Air Power Survey "Effects and Effectiveness" Report, 11 December 1992.

[37] Ed Mann's argument in *Thunder and Lightning* is that, because the generic Air Force officer would rather have root canal than read about air power doctrine, the institution has repeatedly disarmed itself intellectually by ignoring the "whys" of air power and concentrating instead on the "hows" of flying and fighting (Kuehl, *Airpower Journal*, Spring 1996, p. 122).

[38] David MacIsaac, "Voices from the Central Blue: The Air Power Theorists," *Makers of Modern Strategy from Machiavelli to the Nuclear Age*, ed. Peter Paret (Princeton, New Jersey: Princeton University Press, 1986), pp. 624 and 647.

[39] Carl H. Builder, *The Icarus Syndrome: The Role of Air Power Theory in the Evolution and Fate of the U.S. Air Force* (New Brunswick and London: Transaction Publishers, 1994), p. 155.

[40] Lieutenant Colonel Donald R. Baucom, "The Coming of the German Jets," *Air Force Magazine*, August 1987, p. 90. See also, Lieutenant General Carl Spaatz, "Enemy Jet-Propelled Fighters," memorandum to General Arnold, 23 July 1944, Spaatz Papers, Box 50, Folder marked "Aircraft Development—Jet Propelled," Library of Congress.

[41] As Perry Smith pointed out in 1970, perhaps the closest parallel to the special bond between American aviators and their planes is that between cavalry officers and their horses. To the American pilot, "the airplane was not just a new and exciting weapon; it was what carried him miles behind enemy lines and brought him back; it was a personal possession which was given a personal, usually feminine, name, kissed upon return from a mission, and painted with a symbol for each enemy plane shot down or bombing mission completed" (Perry McCoy Smith, *The Air Force Plans for Peace: 1943-1945* (Baltimore and London: Johns Hopkins Press, 1970), p. 18).

[42] Alexander S. Cochran, "Service Perspectives on the Present and Future: A Minority View on the Wild Blue Yonder," unpublished paper, Conference on Interservice Rivalry and the American Armed Services, Monterey, California, 6 March 1996, p. 5.

[43] Colonel Alan L. Gropman, "Analysis by Hyperbole," *Air University Quarterly Review*, September-October 1983, p. 91.

[44] General T. R. Milton, "Forecasting for Security," *Air Force Magazine*, August 1986, p. 99.

[45] Colonel Jeffrey R. Barnett, *Future War: An Assessment of Aerospace Campaigns in 2010* (Maxwell AFB, Alabama: Air University Press, January 1996), p. xx.

[46] Dr. Gene H. McCall and Major General (USAF, Ret.) John A. Corder, *New World Vistas: Air and Space Power for the 21st Century*, Summary Volume (Washington, DC: December 1995), p. 3.

[47] See McCall and Corder, *New World Vistas*, Summary Volume, pp. A-3 and A-4.

[48] As Tony Mason has rightly noted, the American F-4 was superior to Soviet-produced contemporary aircraft (Air Vice Marshal Tony Mason, *Air Power: A Centennial Appraisal* (London & Washington, DC: Brassey's, 1994), p. 78).

[49] Andrew F. Krepinevich, Jr., *The Army and Vietnam* (Baltimore and London: Johns Hopkins University Press, 1986), pp. 261-264.

[50] Bernard B. Fall, *Street Without Joy* (New York: Schocken Books, 1961), pp. 105-106, 285, 302-303, 312-329.

[51] Mark Clodfelter, *The Limits of Air Power: The American Bombing of North Vietnam* (New York: The Free Press, 1989), pp. ix-xi, 134-146, and 194-202; Ronald D. Spector, *After Tet: The Bloodiest Year in*

Vietnam (New York: The Free Press, 1993), p. 314; Colin S. Gray, "On Strategic Performance," *Joint Force Quarterly*, Winter 1996-96, p. 30.

[52] Stanley Karnow, *Vietnam: A History* (New York: Viking Press, 1983), pp. 17-18.

[53] Spector, *After Tet: The Bloodiest Year in Vietnam*, pp. 311-313 and 315.

[54] Gray, "On Strategic Performance," p. 31.

[55] Mark E. Hubbard in Major General William E. Kepner, "The Long Reach: Deep Fighter Escort Tactics," Eighth Fighter Command, 29 May 1944, p. 10. This wartime publication was developed by asking some of Eighth Air Force's more seasoned fighter pilots and fighter leaders for accounts of their own experiences flying long-range-escort missions over occupied Europe in late 1943 and early 1944 (*ibid.*, p. 3). It contains of twenty-six such accounts plus General Kepner's introduction.

[56] Raymond F. Toliver and Trevor J. Constable, *The Blond Knight of Germany* (New York: Doubleday, 1970), p. 173. Hartmann had exceptional visual acuity that usually enabled him to spot enemy planes long before his comrades (*ibid.*).

[57] *Armed Forces Journal International*, May 1974, p. 30; R. Frank Futrell, William H. Greenhalgh, Carl Grubb, Gerard E. Hasselwander, Robert F. Jakob, and Charles A. Ravenstein, *Aces and Aerial Victories: The United States Air Force in Southeast Asia 1965-1973* (Washington, DC: Office of Air Force History and Air University, 1976), p. 157. The U.S. Air Force was credited with 135 fighter kills (plus two more by B-52 tail gunners) for 60 losses; the U.S. Navy and Marine Corps fighters scored 55 kills for 15 losses.

[58] *Project Red Baron III: Air-to-Air Encounters in Southeast Asia* (Cameron Station, Virginia: Defense Documentation Center, June 1974), Vol. I, *Executive Summary*, p. 24. As of the summer of 1975, instructors at the U.S. Navy Fighter Weapons School (Topgun) were briefing that 55-60 percent of the American crews downed in Southeast Asia did not see their attacker until after they were hit, and another 25 percent saw the bogey before weapons impact but not in time to do anything about it (Barry D. Watts, personal notes, Topgun Class 04-75, 24 June 1975 lecture). Israeli experience in 1982 revealed a similar pattern. Israeli F-16 pilots, who accounted for about half of Israel's kills in 1982, reported that, excluding gun kills, 60 percent of their victims did not react prior to weapons impact (Colonel James Burton, "Letting Combat Results Shape the Next Air-to-Air Missile," unclassified briefing, January 1985, Slide 6).

[59] Veda, "The Influence of 'Operational Factors' (U)," briefing slides, 14 February 1985, unclassified slide "(U) Definitions (Continued)."

[60] Clarence A. Robinson, Jr., "Fighter, Missile Gains Pressed," *Aviation Week and Space Technology*, 4 April 1977, p. 12.

[61] Lt. Col. R. E. Guild, "AIMVAL Analysis," Headquarters U.S. Air Force, Studies and Analysis, briefing, 25 February 1978, Slide 3 ("Test Objectives"). For details on the five IR missile concepts tested on F-15s and F-14s during AIMVAL, see Clarence A. Robinson, Jr., "Aerial Combat Test to Advance," *Aviation Week and Space Technology*, 25 April 1977, pp. 28-30.

[62] Colonel E. J. Griffith, "ACEVAL: Origin, Description, Results, Applicability," briefing, undated, Slide 2 ("ACEVAL"). Griffith was the Blue Force commander.

[63] Guild, "AIMVAL Analysis," Slide 6 ("Test Trial Matrix for AIMVAL").

[64] Griffith, "ACEVAL: Origin, Description, Results, Applicability," Slide 8 ("Test Matrix").

[65] Lt. Col. S. R. Dvorchak, "Getting It On in the All-Aspect Arena (U)," *Tactical Analysis Bulletin*, Vol. 79-2 (special), 25 July 1979, pp. 3-4 and 18. As Dvorchak later observed, if you view ACEVAL strictly as a test of competing hardware, the results become "incomprehensible" (telephone conversation, 6 October 1986).

[66] Guild, "AIMVAL Analysis," Slide 7 ("Summary Observations—Test Environment"); Griffith, "ACEVAL: Origin, Description, Results, Applicability," Slide 3 ("Test Design") and Slide 7 ("Test Hardware").

[67] Veda, "AMRAAM OUE Lessons Learned Briefing (U)," Dayton, Ohio, 11 April 1984, Slide 9 ("(U) AMRAAM OUE Test Matrix").

[68] S. R. "Shad" Dvorchak, "On the Measurement of Fog," briefing to the Military Operations Research Society, June 1986, Slide 7 ("Foggy Variables Are Important"). The source of this conclusion was Veda's "AMRAAM OUE Lessons Learned Briefing (U)," SECRET, 3 August 1983, Slide 41 ("(U) Overall Comments"). This slide was later declassified.

[69] Theodore von Karman, *Toward New Horizons* (Washington, DC: Army Air Forces Scientific Advisory Group, 15 December 1945), p. v.

[70] See Warden, *The Air Campaign*, p. xxv.

[71] I. B. Holley, Jr., *Ideas and Weapons* (Washington, DC: U.S. Government Printing Office, 1983), pp. 13 and 19.

[72] Note that the Sparrow III missile first saw operational service on the U.S. Navy's F3H-2 Demon (*McDonnell F-4 Phantom: Spirit in the Skies*, ed. Jon Lake (Westport, Connecticut: Airtime Publishing, 1992), pp. 22-23). However, the Demon was never very successful due primarily to engine problems (Jeff Ethell, *F-15 Eagle* (Shepperton, Surrey: Ian Allan Ltd., 1981), p. 9).

[73] Alain C. Enthoven and K. Wayne Smith, *How Much Is Enough? Shaping the Defense Program, 1961-1969* (New York: Harper and Row, 1971), p. 263; also, René Francillon, *McDonnell F-4D* (Arlington, Texas: Aerofax, Inc., 1985), pp. 1-2.

[74] *Born in Battle: Israel's Air Force*, Issue 2, Eshel-Dramit, 1978, p. 47.

[75] Nadav Safran, *Israel: The Embattled Ally* (Cambridge, Massachusetts, and London: Belnap Press, 1978), p. 275; also, Mason, *Air Power: A Centennial Appraisal*, p. 78.

[76] Colonel James G. Burton, "Letting Combat Results Shape the Next Air-to-Air Missile," unclassified briefing, January 1985, Slides 3 and 5. U.S. fighters are credited with downing 190 North Vietnamese aircraft in aerial combat from April 1965 to January 1973 (R. Frank Futrell, William H. Greenhalgh, Carl Grubb, Gerald E. Hasselwander, Robert F. Jakob, and Charles A. Ravenstein, *Aces and Aerial Victories: The United States Air Force in Southeast Asia 1965-1973* (Washington, DC: Office of Air Force History and Air University, 1976), p. 157; *Armed Forces Journal International*, May 1974, p. 30.

[77] Zeev Schiff, "The Israeli Air Force," *Air Force Magazine*, August 1976, p. 37.

[78] Burton, "Letting Combat Results Shape the Next Air-to-Air Missile," Slides 3 and 5.

[79] Victor Flintham, *Air Wars and Aircraft: A Detailed Record of Air Combat, 1945 to the Present* (New York: Facts on File, 1990), p. 70; Burton, "Letting Combat Results Shape the Next Air-to-Air Missile," Slides 3 and 5.

[80] Burton, "Letting Combat Results Shape the Next Air-to-Air Missile," Slide 5.

[81] The limitations of the early Sparrow IIIs for fighter-versus-fighter combat were common knowledge in the U.S. F-4 community by 1967. The AIM-7Cs and AIM-7Ds used during most of the Rolling Thunder period proved far less reliable in actual combat conditions than the engineers had predicted; and, not until the AIM-7E-2 version appeared in 1968 did the Sparrow III achieve a minimum-range capability compatible with close-in dogfights. The Vietnam-era versions of the missile, with their vacuum-tube electronics and hand-soldered wiring, proved particularly hard to maintain under the stress of regular launches and recoveries aboard aircraft carriers.

[82] Burton, "Letting Combat Results Shape the Next Air-to-Air Missile," Slide 9.

[83] During the Gulf War 41 air-to-air victories were officially credited to Coalition fighters. Since three of these kills involved Iraqi pilots flying into the ground after being engaged, there were 38 kills credited to Coalition air-to-air missiles (36) or guns (2). Of these 38 kills, 24 (just over 63%) were achieved with the radar-guided AIM-7M (Major Lewis D. Hill, Doris Cook, and Aron Pinker, *Part I: A Statistical Compendium* in *Gulf War Air Power Survey*, Vol. V, *A Statistical Compendium and Chronology* (Washington, DC: U.S. Government Printing Office, 1993), Table 206, Coalition Air-to-Air Kill Matrix). In 15 of these 24 AIM-7M kills, the engagements opened with BVR shots (Barry D. Watts and Thomas A. Keaney, *Part II: Effects and Effectiveness* in *Gulf War Air Power Survey*, Vol. II, *Operations and Effects and Effectiveness* (Washington, DC: U.S. Government Printing Office, 1993), p. 113). Ten of these BVR engagements occurred during daylight and five at night. Also, there were some occasions on which the initial BVR shot missed and the kill was achieved by a subsequent missile fired after the pilot visually acquired the bogey.

[84] Watts and Keaney, *Part II: Effects and Effectiveness* in *Gulf War Air Power Survey*, Vol. II, *Operations and Effects and Effectiveness*, pp. 122-123.

[85] Thomas Friedman, et al., "Can Bombing Win a War?," NOVA Show #2002, 19 January 1993 (air date), Journal Graphics, p. 1.

[86] David R. Mets, *The Quest for a Surgical Strike Capability: The United States Air Force and Laser Guided Bombs* (Eglin Air Force Base, Florida: Office of History, Armament Division, Air Force Systems Command, 1987), pp. 62-64.

[87] *Ibid.*, p. 67. That half of the LGBs can be expected to land within 20 feet of their aim points means that the weapon has a circular error probable (CEP) of 20 feet.

[88] Colonel Delbert Corum, et al., "The Tale of Two Bridges," *The Tale of Two Bridges and the Battle for the Skies over North Vietnam*, ed. Major A. J. C. Lavalle (Washington, DC: U.S. Government Printing Office, 1976), pp. 79-92.

[89] Mets, *The Quest for a Surgical Strike Capability*, p. 87.

[90] *Ibid.*, pp. 26-31.

[91] See, for example, General (USAF, Ret.) William W. Momyer, *Air Power in the Three Wars (WW II, Korea, Vietnam)*, eds. Lieutenant Colonel A. J. C. Lavalle and Major James C. Gaston (Washington, DC: U.S. Government Printing Office, 1978), pp. 149-150, 236, 241, and 328.

[92] Colonel Phillip S. Meilinger, "Ten Propositions Regarding Airpower," *Airpower Journal*, Spring 1996, pp. 63-65. See also Barnett, *Future War: An Assessment of Aerospace Campaigns in 2010*, pp. 10-12. For an earlier version of this thesis, see Lieutenant Colonel Edward Mann, "One Target, One Bomb: Is the Principle of Mass Dead?", *Airpower Journal*, Spring 1993, pp. 35-43.

[93] During the eleven days of B-52 strikes against North Vietnam in late December 1972 (Linebacker II), there was only one period of about eight hours in which the weather was good enough for LGB employment (Oral history interview with General John W. Vogt, conducted by Robert M. Kipp, 22 August 1975, K105.5-210, p. 8). Targets attacked with LGBs during this brief period were the "Hanoi power plan, railroad classification yard, and radio station" (Momyer, *Air Power in Three Wars*, p. 241).

[94] Mets, *The Quest for a Surgical Strike Capability*, pp. 66 and 109-111.

[95] Mets, *The Quest for a Surgical Strike Capability*, p. 106. Tactically, the PAVE KNIFE pods employed during Linebacker were a forerunner to PAVE TACK insofar as both enabled a single aircraft to illuminate a target with laser energy and deliver a bomb against it. Prior to PAVE KNIFE one plane had to illuminate the target while others released bombs into the basket over the target. PAVE KNIFE, however, provided no serious capability for attacking precision targets at night.

[96] Headquarters U.S. Air Force, Management Information Division, *United States Air Force Statistical Digest: Fiscal Year 1973*, 31 July 1974, Table 34, p. 86; *United States Air Force Statistical Digest: Fiscal Year 1974*, 15 April 1975, Table 37, p. 73.

[97] Keaney and Cohen, *Revolution in Warfare? Air Power in the Persian Gulf*, p. 171.

[98] The French Somua 35 and B. I. bis tanks were considered superior to any of the German panzers (Douglas Porch, "Why Did France Fall?," *The Quarterly Journal of Military History*, Spring 1990, p. 33). Similarly, the British Matilda had stronger armor than the German tanks, and the 37-millimeter gun on the German Mark III was inferior to the British two-pounder (F. W. von Mellenthin, *Panzer Battles: A Study of the Employment of Armor in the Second World War*, trans. H. Betzler (Norman, Oklahoma: University of Oklahoma Press, 1956), p. 12). On the other hand, the operational ranges and turret sizes of the panzers used in May 1940 favored the Germans.

[99] Phillip A. Karber, Grant Whitley, Mark Herman, and Douglas Komer, "Assessing the Correlation of Forces: France 1940," BDM Corporation, BDM/W-79-560-TR, June 1979, pp. 2-3; also, Trevor N. Dupuy, *Understanding War: History and Theory of Combat* (New York: Paragon House, 1987), pp. 93-94. While the Germans had a substantial edge in total combat aircraft in May 1940, the opposing sides were nearly equal in single-/twin-engine fighters (ignoring British fighter strength retained in England).

[100] Andrew W. Marshall, "Some Thoughts on Military Revolutions," OSD/Net Assessment, 27 July 1993, p. 2; and, Andrew W. Marshall, statement before the Senate Armed Services Committee, Subcommittee on Acquisition Technology, 5 May 1995, p. 1.

[101] "[Admiral William A.] Owens Says Technology May Lift 'Fog of War': Breakthroughs Could Give Forces Total Command of Future Battlefield," *Inside the Navy*, 23 January 1995, p. 3. See also, Admiral William A. Owens, *Dominant Battlespace Knowledge: The Winning Edge*, ed. Stuart E. Johnson and Martin C. Libicki (Washington, DC: National Defense University Press, October 1995), pp. 14-15; and Owens, "System-Of-Systems: US' Emerging Dominant Battlefield Awareness Promises To Dissipate the 'Fog of

War'," *Armed Forces Journal International*, January 1996, p. 47. The meaning initially associated with Admiral Owens' notion of Dominant Battlefield Awareness was that, by connecting largely existing sensors and shooters together via appropriate information and command-and-control systems, it should be possible to detect, track, and classify most (or all) of the militarily relevant objects moving on land, the surface of the ocean, through the air, or in space within a cube of battlespace some 200 nautical miles on a side.

[102] Lt. Col. Ed Felker, "Information Warfare: A View of the Future," *A Command Perspective: Joint Warfighting Center's Newsletter*, September 1995, p. 18.

[103] Larry Lynn, "Battlefield Dominance and ARPA Focus," Advanced Research Projects Agency (ARPA) memorandum, 29 June 1995, p. 2.

[104] For an extended development of these three points, see Barry D. Watts, "Friction in Future War," a condensed version of which is forthcoming in the 1996-97 edition of *Brassey's Mershon American Defense Annual*; the complete paper is forthcoming from NDU Press as a McNair paper.

[105] Eliot A. Cohen, "The Mystique of U.S. Air Power," *Foreign Affairs*, January/February 1994, p. 122.

[106] Colin S. Gray, "The Changing Nature of Warfare?", *Naval War College Review*, Spring 1996, p. 17.